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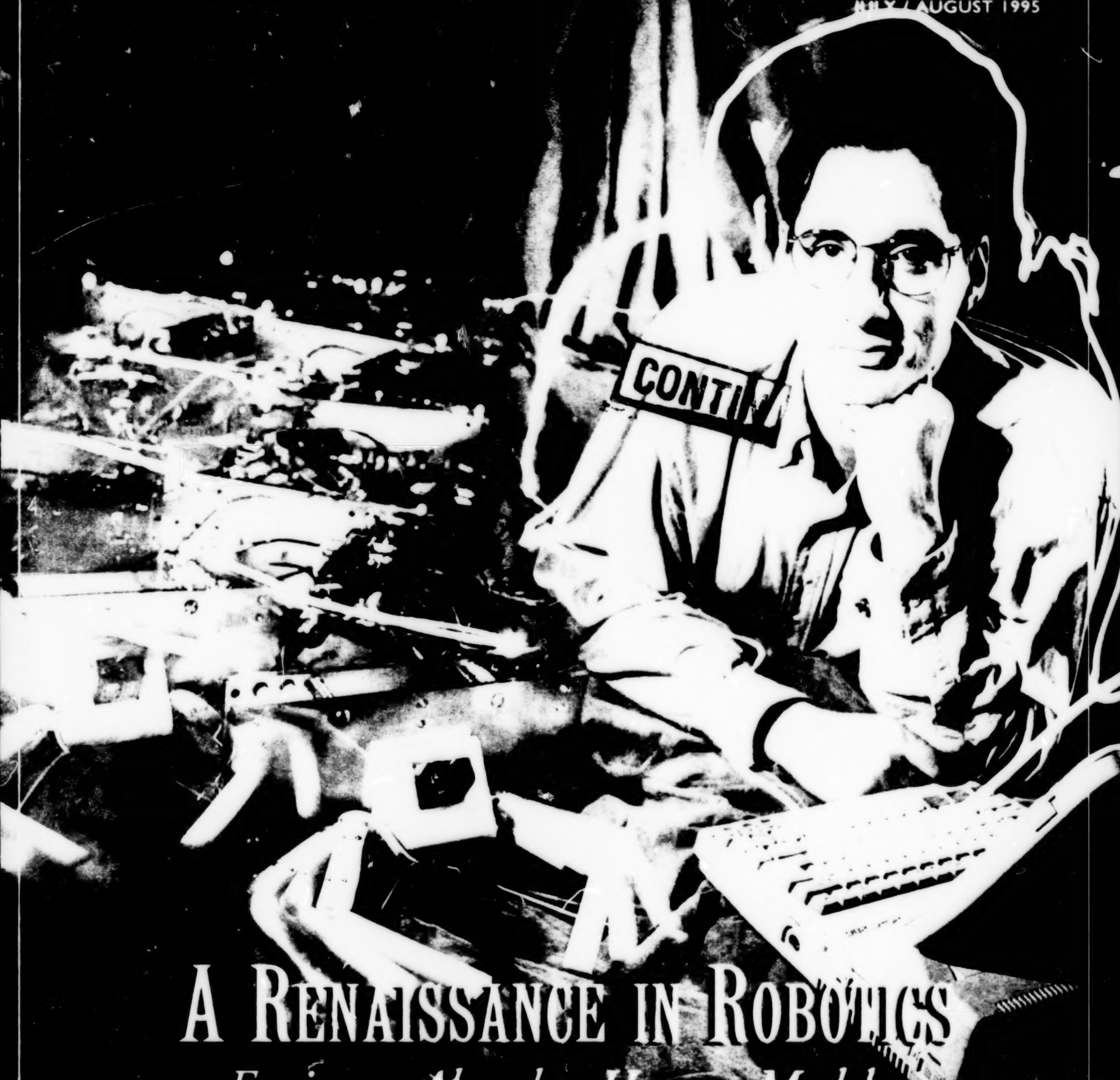

A RENAISSANCE IN ROBOTICS

Engineers Abandon Human Models

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HOW OLD *ARE* WE?

With each new discovery of hominid fossils, scientists learn more about *Homo sapiens'* long pre-history. But they don't know precisely when it began, much less why.

Thus far, most attention has been given to the East African discoveries by the Leakeys (Louis, Mary, and Richard) and Donald Johanson. Their hominid fossils, up to 3+ million years old, were drawn from volcanic-rich strata; with the help of potassium-argon they have been fairly simple to date. (Radiocarbon-14, on the other hand, is used to date most fossils up to 40,000 years old.)

But new technologies are urgently needed to date hominid fossils uncovered in areas having had little or no volcanic activity: e.g., southwestern Europe, the Asian steppes, and the Middle East. Several grantees of NSF's Division of Social, Behavioral, and Economic Research are attacking the problem head-on, producing what some have called "the new revolution in anthropological dating."

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* University of Southern California earth scientist **Teh-Lung Ku** is in Zhoukoudian, People's Republic of China, site of the "Peking Man" fossils guessed to be between 300,000 and 700,000 years old. Using uranium series technologies enhanced with thermal ionization mass spectrometry, Ku will date more accurately the findings in most of that area's 13 geologic layers.

* **Henry P. Schwarcz**, geologist at McMaster University, Ontario, Canada, employs "electron spin resonance" (ESR) to date heated flint and the tooth enamel of large mammals. ESR, Schwarcz says, can date materials that are a few thousand to more than 2 million years old "with moderate precision at virtually any prehistoric site." He is using ESR to date material from Spain, Italy, Israel, and the Ukraine (through which may have run the hominid highway from Africa to Europe).

* **P. Edgar Hare**, organic chemist at the Carnegie Foundation, uses "amino acid racemization" to date one of the most indestructible fossils commonly found in grasslands and semi-arid areas: ostrich eggshells. Since the big birds were frequent companions of hominids in the African and Asian savannahs, Hare's approach may yield more precise timeframes for what were once home to the ancestors of *Homo sapiens.*

NORTH ATLANTIC PROJECTS YIELD DATA ON PAST ENVIRONMENTS

The harsh landscape of the North Atlantic coast is dotted with the ruins of early Native and Scandinavian communities. Eskimos established settlements in Greenland as early as 2000 B.C. In the 9th century they were joined by Vikings. And both cultures left an imprint on the environment of the region.

Photo by Thomas Amorosi

▶ Jim Woolett recovers a bone hair comb while excavating "middens" or ancient garbage piles in Svalbard, Iceland. In the background, the same area before the excavations began in 1988.

Investigations of the earth's climatic history, such as the recent Greenland Ice Sheet Project, have provided archaeologists and other social scientists of the region with unique and detailed information on the environmental conditions and changes surrounding earlier and in bridging the divides of nature and culture as well as between scattered geographical locations.

Since 1993, Hunter College of the City University of New York has been home to the North Atlantic Biocultural Organization (NABO), a multidisciplinary research cooperative dedicated to improving communications between natural and social scientists of the North Atlantic. Founded by anthropologist Tom McGovern and colleagues at Hunter's Bioarchaeological Laboratory, NABO provides an organizational infrastructure for researchers to share information and resources from a variety of fields, including zooarchaeology, history, paleoentomology, [illegible]limatology, and cul[illegible]

Photo by Bobbi Brickman

▶ Thomas Amorosi creates a plan of a stone and turf wall found at a site in Bogafjord-Estryi, Iceland.

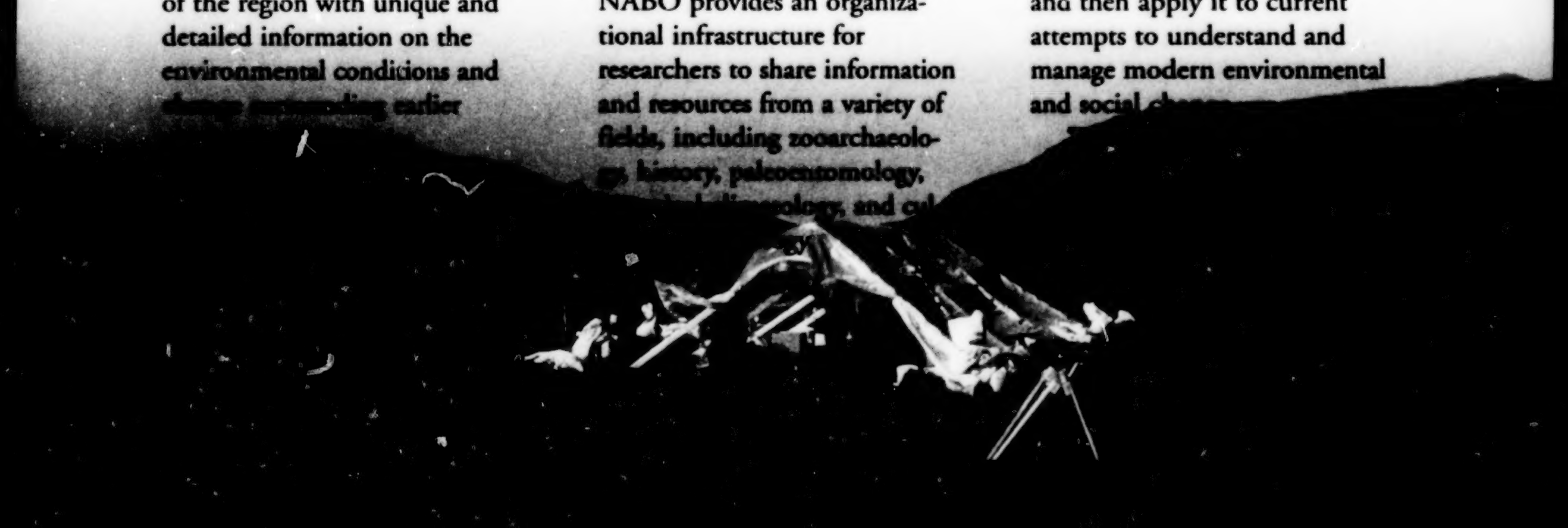
With grants from three NSF programs (the Office of Polar Programs' Arctic Social Science Program and Arctic Systems Science Program, and the U.S. Global Change Research Program), as well as from Britain and Norway, NABO has built up collections of archaeological and ecological samples and case studies from Norway, Greenland, Arctic Canada, and the British Isles.

About half of NABO's funds support specific cooperative projects, including field work by advanced graduate students. Currently more than 180 scholars from 10 countries are involved in NABO research efforts.

Other cooperative projects include studies of long-term northern farming adaptations in Iceland and Norway in coordination with studies of long-term northern hunting strategies in Greenland and Labrador.

In addition, simulation models, field projects, and documentary research are used to investigate the impacts of global change on societies with different economic and social organization.

NABO shares the overall perspective of the growing *Historical Ecology* movement, McGovern says. NABO scholars work to integrate the diverse evidence for past human interaction with land and resources and then apply it to current attempts to understand and manage modern environmental and social ch[illegible]



A RENAISSANCE IN ROBOTICS

Star Wars' Artoo-Detoo photo courtesy of 20th Century-Fox.

Engineers Abandon Human Models

There is nothing simple about being human. Just picking up a soft drink, opening it, and taking a drink requires the combined efforts of a few hundred muscles, nerves, and brain cells. For that reason, many robotics engineers have abandoned the human model to work on simpler forms of mechanical "life." The switch comes from a change in philosophy as well as advances in engineering, says Presidential Faculty Fellow Gregory Chirikjian.

"Robotics has been motivated by the expectations of science fiction," says Chirikjian, an assistant professor at Johns Hopkins University. "No one questioned whether robots should be anthropomorphized."

For years, the man-machine image created in 1917 by Czech playwright Karel Capek's *RUR* (Rossum's Universal Robots) dominated the design process. Capek's term robot came from Czech "menial laborer" or "servant." Other writers expanded the man-machine myth, creating robot laws, robot culture, and robot worlds. In this atmosphere, early robotics engineers worked on human substitutes — machines that needed large computers and power sources to approach tasks in the same way as their human model.

But there's a new trend emerging in robot design. Minimalist robotics engineers use as little hardware and software as possible, take advantage of high-end mathematics to find the most efficient pattern for moving things, and exploit low-tech mechanics such as pistons and spring latches. The robots themselves resemble snakes, amoebas, insects, rolling refrigerators, and vises. In addition, these robots are comparatively cheap, and they get their jobs done reliably.

Robotics Priesthood

The minimalist approach is pushing America into a "robotics renaissance," says NSF's Howard Moraff, who directs the Robotics and Machine Intelligence Program in the Division of Information, Robotics, and Intelligent Systems (part of the Computer and Information Science and Engineering Directorate). He expects the renaissance to hit its stride when robots become more user-friendly for factory workers and others.

Today, maintenance and retooling are the province of what Moraff calls "the robotics priesthood." If a robotic arm fails, the typical machine shop cannot repair it. If repairs take a long time, productivity can suffer.

"Robotics needs to be graspable and usable by people who are not sophisticated experts," he says.

Comparing robotics development to the last 40 years of

ON THE COVER:

Johns Hopkins' Greg Chirikjian uses a computer to manipulate his snake-like robotic arm, which can reach almost 33,000 different points. Chirikjian says this flexibility is sufficient for many industrial applications.
Photo by John Goell.

calculator and computer development, Moraff says, robots are in the bulky and not easily accessible, "mainframe" stage. But just as he now owns half a dozen calculators, Moraff says "as soon as robots are handy, I'm going to have a bunch."

They are already handy for many businesses. After a dismal showing in the 1980s, when robots proved too finicky for the rough-and-tumble world of factories, robot purchases were up 30 percent in 1993 and another 25 percent last year, says Moraff.

The key, according to Moraff and many NSF grant recipients, is to develop robots that:

- can manage a very broad group of tasks,
- do not break down easily,
- do not need major adjustments for minor product changes,
- and do not cost a fortune.

The Economy Model

Cost is the driving force in this minimalist movement, says Johns Hopkins' Chirikjian. Industries now use expensive robots with elaborate feedback loops and human-like potential for continuous motion. But Chirikjian asked if industries really needed the whole range of motion. They really didn't. So Chirikjian has come up with some less expensive alternatives.

In his basement laboratory, Chirikjian keeps the standard manufacturer's robotics arm and pedestal near the wall. With a price tag of several hundred thousand dollars, this robot arm can swing freely.

Chirikjian's thousand-dollar snake-like robotic arm lies on the floor nearby. The eight-foot arm is made of 15 pneumatic pistons arranged in groups of three, and it is the opening and closing of the pistons that moves the arm. With someone at the controls, the snake-arm works like a hesitant cobra, curling to one position, stretching to another, grabbing paper with its gripper, and setting it down in a different place. With a repertoire of almost 33,000 positions, Chirikjian says the arm is good enough for many industrial applications. Even so, he is working on another arm which, with more pistons arranged in groups of six, will reach 64 billion distinct points. That, he says, "is getting pretty close to continuous motion."

Not only is a piston-driven arm cheaper to manufacture than the standard industrial arm, but by limiting the points the arm can reach, Chirikjian says he has eliminated software needed for the elaborate feedback loops that keep current arms from over-extending. The software for his arms need only tell the pistons to open or close.

Setting It Right

Parts-feeding is a bottleneck area for manufacturing, says Moraff, and efficient robots can help. In simple terms, parts-feeding means getting a bolt, electronic board, or other widget down the conveyor belt in the correct position so the next robot can grasp it.

Industry now uses "hard automation" designed to move one specific bolt or board. If the design of the product changes, the hardware has to be redesigned. Such retooling

Photo by Louis Rosenstock

▶ **Graduate student Amit Pamecha works on the prototype of Chirikjian's shape-changing robot. Chirikjian hopes to see morphing robots used to hold up earthquake-damaged buildings and to capture errant satellites.**

Photo courtesy of Transfer Research Corporation

▶Transfer Research Corporation's *HelpMate* robot uses a laser beam system to navigate the halls of hospitals, delivering food and sterile equipment.

slows new product development.

NSF Young Investigator Ken Goldberg, of the University of Southern California, has a solution. Based on geometric algorithms, Goldberg developed a parts-feeder that can work on many sizes and shapes of parts without changing hardware.

Goldberg's solution seems too simple to be true. His patented robot looks like a vise with two parallel jaws. In three moves, it turns the part and pushes it, hitting the right spot every time.

Goldberg proved that his algorithm is complete: that it will work for a broad class of industrial parts. He is now working with Adept Technology to develop a commercial version.

"Humans couldn't do this job very accurately," Moraff comments, "but a robot can do it with a minimum of software."

In fact, Goldberg's machine requires so little software that, he says, "some people wouldn't call it a robot."

Seeing the Light

Not every robot can be improved by a minimalist approach, but sometimes mechanically simple improvements make a big difference. Carl Weiman, a researcher at Transfer Research Corporation (TRC), a Connecticut-based company that has several NSF Small Business Innovation Research grants, says TRC's *HelpMate* robot will remain complex because it has a complex set of tasks to accomplish.

The size and shape of a rolling refrigerator, *HelpMate* travels through hospitals delivering food and sterile equipment. *HelpMate's* new navigation system enables the robot to operate efficiently in an environment filled with humans who sometimes get in the way.

HelpMate was first equipped with SONAR, but the engineers were not satisfied. TRC then developed a Light Direction and Range (LIDAR) navigating device that uses an infrared laser, bouncing light instead of sound off walls. LIDAR operates more quickly than SONAR. It also lets robots operate where humans cannot go, such as outer space. Both NASA and the military use LIDAR.

Beyond Asimov

Freed from the necessity of mimicking the human image, and equipped with efficient micro-chips that can control tiny robots, robotics engineers may not stay in the minimalist realm. But they plan to keep building function-driven machines which will push robotics out of the man-machine robotic image of science fiction into practical realms.

One of Chirikjian's ongoing works is a "morphing" or shape-changing robot. The robot will be a group of hexagons that use a spring latch to combine and recombine — somewhat like computer-driven Legos™. "Say there's an earthquake, and a building is a little shaky. You get a truckload of these and they reconfigure themselves to hold up the building," he explains.

Holding up buildings and bridges and cleaning up hazardous waste — this is the future that NSF's Moraff also foresees for robots. He wants them to do the work that humans cannot or do not want to do. Moraff tells about people working on medical robots that will clean out arteries, and robots for the elderly to lean on. Or, for common use, Moraff recalls a suggestion by Rodney Brooks of Massachusetts Institute of Technology. Brooks wants to use a whole slew of robots for housecleaning, Moraff explains. "Little insect robots would be programmed to find lint, pick it up and stuff it in their bellies. When they're full, they could dump it in a central place, or into an incinerator, or...."

Moraff smiles and stops. He and his colleagues have plenty of other suggestions. ○

NATURE AND CULTURE SHAPE HOW BABIES SLEEP

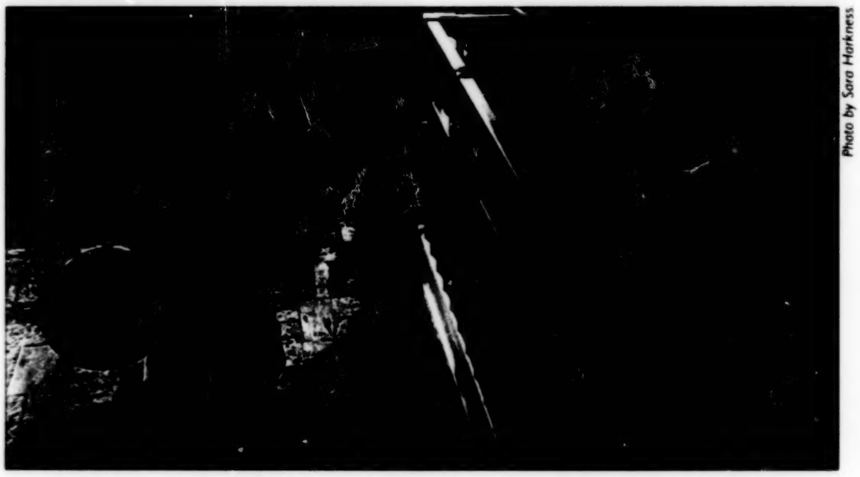


Photo by Sara Harkness

▶ Harkness' study showed that the sleep patterns of Dutch children, such as this child, are different from the sleep patterns of American children.

Few things in life are more natural than taking care of a baby. Give the baby a bottle, set her down in her crib, and try not to wake her.

But according to several NSF-funded anthropologists who presented their work at the 1995 meeting of the American Association for the Advancement of Science, many of these "natural" ways of caring for a child are actually cultural. There is a wide spectrum of possible sleep patterns for babies and parents, anthropologists say.

Unlike standard practice in the United States, many parents in other countries sleep with their babies in the same bed (called co-sleeping). Baby and adult may wake at intervals for food and changing. At the other end of the spectrum, parents in some countries encourage more sleep than do their U.S. counterparts.

Mothers in southwest Kenya co-sleep, reported Robert LeVine of Harvard University, who worked there during the 1960s and 1970s. In addition, babies were breast-fed and carried continuously for about 17 months.

LeVine reported that this practice encourages the child to eat whenever hungry and discourages crying, since food and comfort are readily available. This strategy means the child gains weight quickly after birth, LeVine reports, which is an important aim for an area with high infant mortality.

Other anthropologists reported that benefits of co-sleeping may include a decreased risk of Sudden Infant Death Syndrome (SIDS), which is thought to occur partly because a deep-sleeping baby cannot wake up. Sleeping next to someone keeps the infant in the lighter stages of sleep. It may also mean that both parent and child sleep less than eight hours at night and may augment that by resting during the day.

But other people think children need long periods of uninterrupted sleep. Sara Harkness, of Pennsylvania State University, found that children in a community in Holland slept longer periods than children of the same age in Cambridge, Massachusetts.

Harkness reported that by six months, Dutch children were sleeping two hours more than Cambridge children.

While the sleep differences narrowed as the children got older, Harkness said that Dutch children continued to go to bed comparatively early. "It seemed that all seven to eight-year-old children in Bloemenheim, except for our son, were routinely in bed by 7:30, " she says. "We were definitely out of line culturally."

The significance of the studies, Harkness and others say, is the realization that sleeping patterns are not defined by what is "biologically natural." Instead, each culture and many sub-cultures develop different sleep schedules that reflect differing local and cultural circumstances. ○

WOMEN IN SCIENCE NEED MORE THAN "CRITICAL MASS"

Universities will not succeed in recruiting and retaining women scientists and engineers if their only aim is to attain a "critical mass" of women, according to a study by Henry Etzkowitz, a sociologist at SUNY-Purchase. In addition, he says, institutions also need to examine departmental structures, which may be discouraging female participation.

Etzkowitz, funded by NSF's Studies Program (in the Directorate for Education and Human Resources), examined the experiences of women graduate students and faculty at 30 departments representing five disciplines (biology, chemistry, physics, computer science, and electrical engineering). His study, published in *Science* (Oct. 7, 1994), was presented at the 1995 American Association for the Advancement of Science meeting.

The biggest problems facing women at the universities he studied are feelings of isolation and difficulties in balancing science and family. Neither problem is solved simply by having more women in the department, Etzkowitz writes, although the situations were sometimes improved.

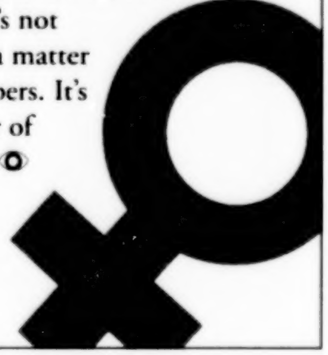
Even with more women, a department may still have so many divisions that women continue to be isolated, he writes. And senior female faculty may not provide a role model of a balanced life any more than do male faculty members.

"Senior female scientists typically shared the values and work styles of older men; their narrow focus failed to meet the needs of most younger women," he writes. "In contrast, some younger women (and a few men) struggled to create an alternative scientific role, balancing work and nonwork issues.

"The scientific role thus bifurcates along generational and gender fault lines," he writes.

Among the results of these institutional structures are a continuation of the entrenched culture of academic science, often dominated by white men, and a large attrition of female Ph.D students, he writes.

"A significant increase in the number of women in academic science is unlikely to occur simply by increasing the numbers of women who embark on a scientific career," Etzkowitz says. "It's not strictly a matter of numbers. It's a matter of power."



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